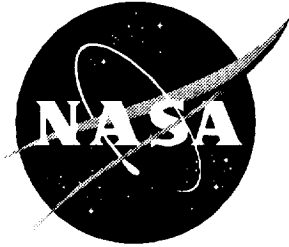


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Study of the TRAC Airfoil Table Computational System

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Foreword

The research reported in this document has been performed under the contract NAS 1-19935-T20, Task Assignment No.20, from Langley Research Center, the National Aeronautics and Space Administration. Dr. Henry E. Jones has been the technical monitor, who provided many helpful suggestions during the course of the study. His assistance is truly appreciated.

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Study of the TRAC Airfoil Table Computational Method

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Summary

The report documents the study of the application of the TRAC airfoil table computational package (TRACFOIL) to the prediction of 2D airfoil force and moment data over a wide range of angle of attack and Mach number. The TRACFOIL generates the standard C-81 airfoil table for input into rotorcraft comprehensive codes such as CAMRAD. The existing TRACFOIL computer package is successfully modified to run on Digital alpha-workstation and on Cray-C90 supercomputer. A step-by-step instruction for using this package on both computer platforms is provided. Application of the newer version of TRACFOIL is made for two airfoil sections. The C-81 tables obtained using the TRACFOIL method are compared with those of wind-tunnel data and results are presented.

1. The TRACFOIL Method

The TRACFOIL is a Computational Fluid Dynamics (CFD)-based computer package for generating the standard C-81 airfoil tables, which was developed for the HP9000/735 computer platform by Boeing-Mesa. The C-81 table provides lifting force, drag force and pitching moment for arbitrary airfoil section at various flow conditions, where angles of attack range from -180° to 180° and free-stream Mach numbers range from 0.0 to 1.0. The table is used for input into rotorcraft comprehensive codes such as CAMRAD.

The structure of the TRACFOIL computational package is sketched in Figure 1. The procedures for generating the C-81 tables consist of two major steps. The first major step is to compute aerodynamic data over inner region - the Region C as shown in Figure 2, where the CFD flow solver ARC2D is used. The ARC2D is an implicit central-differenced two-dimensional Navier-Stokes CFD code. This step is performed through a UNIX command file, sweep.com, where computational grid is provided through a hyperbolic grid generator, HYGRID. The second major step is to interpolate the data into Region B of Figure 2 using cubic-spline-under-tension technique, where CFD-predicted data over region C and wind-tunnel data over region A are used during interpolation. This step is performed through a utility file, util.f.

The sequence of events leading to the generation of a C-81 table is semi-automated, where some man-interference is needed during the process. A step-by-step instruction for using the TRACFOIL package is provided in the following section.

2. The Use of TRACFOIL

The existing TRACFOIL computational package is successfully modified to run on both NASA LaRC's Digital alpha-workstation and NAS Cray-C90 supercomputer. A modified version of TRACFOIL is obtained. The following is a step-by-step instruction on using the TRACFOIL package on both computer platforms:

Step 1 - Preparation: A modified version of TRACFOIL package is stored under the directory "/Tracfoil-c81/Code". Create two sub-directories under "/Tracfoil-c81" for each airfoil geometry as working directories, then copy appropriate files into these two working directories. Under the directory "/Tracfoil-c81", type

```

mkdir GenerateGrid-sample1
mkdir ProduceTable-sample1
cd Code
cp hh02.in ../GenerateGrid-sample1
cp hygrid.f ../GenerateGrid-sample1
cp arc2d.f ../ProduceTable-sample1
cp create.f ../ProduceTable-sample1
cp header.txt ../ProduceTable-sample1
cp util.f ../ProduceTable-sample1
cp naca0012-1.c81 ../ProduceTable-sample1
cp naca0012-2.c81 ../ProduceTable-sample1

```

Step 2 - Generating Grid: Compile the grid generator, hygrid.f, and then run the executable file, hygrid, in interactive mode. Type

```

cd GenerateGrid-sample1
f77 hygrid.f           note: — on Digital alpha
f90 hygrid.f           note: — on Cray-C90
mv a.out hygrid
hygrid                 note: — on Digital alpha
./hygrid               note: — on Cray-C90

```

A sample interactive session is provided in Figure 3, and a sample airfoil section geometry file is listed in Figure 4. After this step is done, a grid file, grid.dat, is generated. Copy this file to “/ProduceTable-sample1” sub-directory:

```

cp grid.dat ../ProduceTable-sample1

```

Step 3 - Producing executable files: Compile “arc2d.f”, “creat.f” and “util.f” to produce executable files. Type

```

cd ../ProduceTable-sample1
f77 arc2d.f           note: — on Digital alpha
f90 arc2d.f           note: — on Cray-C90
mv a.out arc2d
f77 create.f          note: — on Digital alpha
f90 create.f          note: — on Cray-C90
mv a.out create
f77 util.f            note: — on Digital alpha
f90 util.f            note: — on Cray-C90
mv a.out util

```

Step 4 - Executing "creat": Execute "creat" to generate input files for CFD flow solver, arc2d.f, and a command file, sweep.com. A sample input file for CFD flow solver is listed in Figure 5. To execute "creat", type

create	note: — on Digital alpha
./create	note: — on Cray-C90

Step 5 - Executing "sweep.com": Run "sweep.com" file in batch mode to generate loads table over inner region, where CFD flow solver, arc2d, is repeatedly called to predict aerodynamic data over this region. On Digital alpha-workstation, use "batch" command to run sweep.com. On Cray-C90, type

```
qsub -lmem=4mw -lcpus=25200 sweep.com
```

Modifying the second line of "sweep.com" may be necessary to make sure that the batch job will be running at appropriate directory on Cray-C90 supercomputer.

Step 6 - Editing loads table manually: A loads table, loads.tbl, is generated after the batch job in Step 5 is done. Check the predicted aerodynamic loads in "loads.tbl" for any irregular points and points where solutions fail to converge. Once identified, remove these points from the table. For Mach numbers where all the CFD solutions fail to converge, use those of immediate neighboring lower Mach number. Name the edited loads table into "LOADS.TBL". A sample "LOADS.TBL" file is provided in Figure 6.

Step 7 - Executing "util": The utility, util, interpolates aerodynamic data into Region B and thus produces C-81 tables. To run "util", type

util	note: — on Digital alpha
./util	note: — on Cray-C90

The resulting C-81 tables are stored in "main.c81" for airfoil section and "flap.c81" for flap. The plotting file of the C-81 table variables is stored in "fort.88".

3. Numerical Examples

The modified version of TRACFOIL computational package is applied to two airfoils: non-cambered NACA0012 airfoil and cambered HH02 airfoil. The grid points of 211×51 are used in wrap-around and normal direction, respectively. The entire sequence for generating C-81 tables requires 10 to 11 CPU hours on Digital alpha-workstation and 5 to $5\frac{1}{2}$ CPU hours on Cray-C90 supercomputer.

The C-81 tables for both airfoil sections generated by TRACFOIL package are compared with those of wind-tunnel data. Aerodynamic coefficients are plotted against Mach number for angle of attack ranging from -14° to $+14^\circ$. Figure 7 is the comparison of lifting coefficients for NACA 0012 airfoil, while Figure 8 and Figure 9 are those of drag coefficients and moment coefficients, respectively. Figures 10-12 are same comparisons for HH02 airfoil. It is seen that in general the TRACFOIL generated aerodynamic coefficients compare well with wind-tunnel data for low to moderate Mach numbers and at small angles of attack. The discrepancy between TRACFOIL data and wind-tunnel data appears at high Mach numbers and at large angles of attack. The results are self-explanatory.

4. Concluding Remarks

The existing TRACFOIL computer package is successfully modified to run on Digital alpha-workstation and on Cray-C90 supercomputer. Application of the newer version of TRACFOIL is made for two airfoil sections. The C-81 tables obtained by the TRACFOIL method are compared with those of wind-tunnel data, and the results are presented.

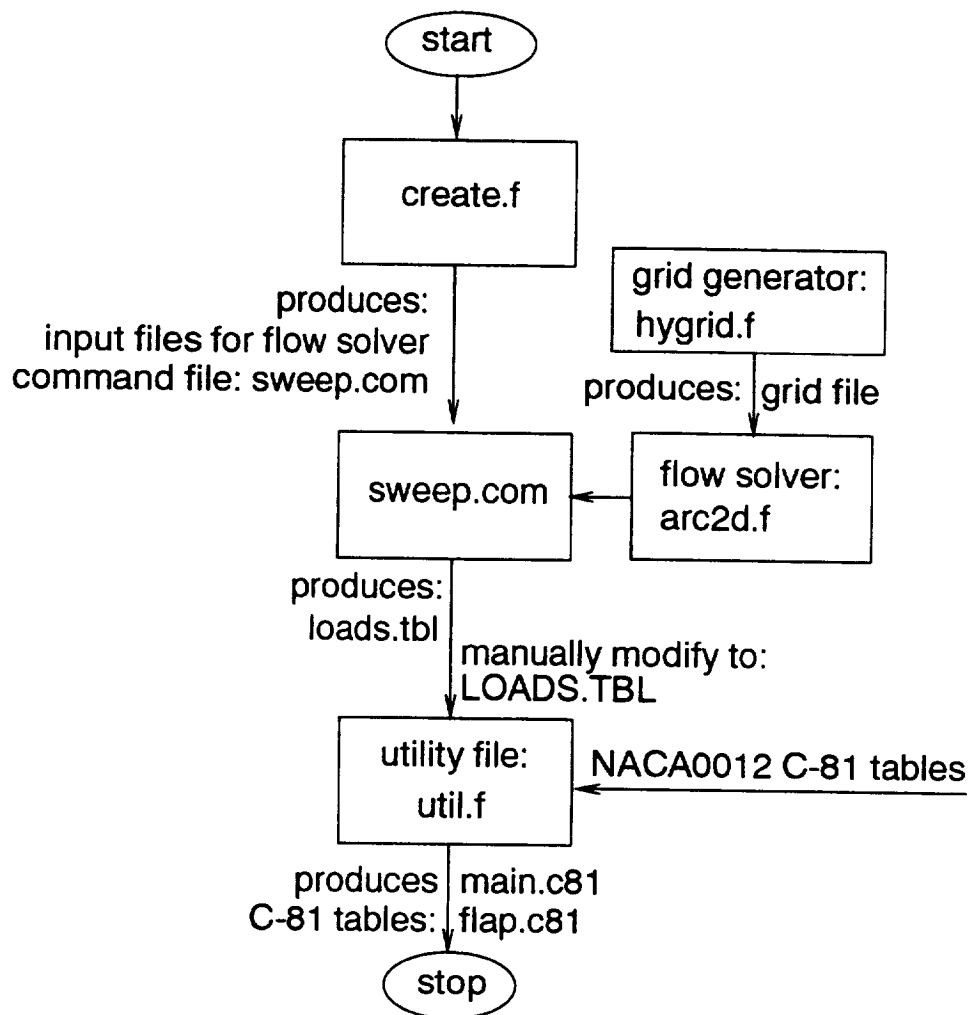


Figure 1. Flow chart depicting the structure of the TRACFOIL method.

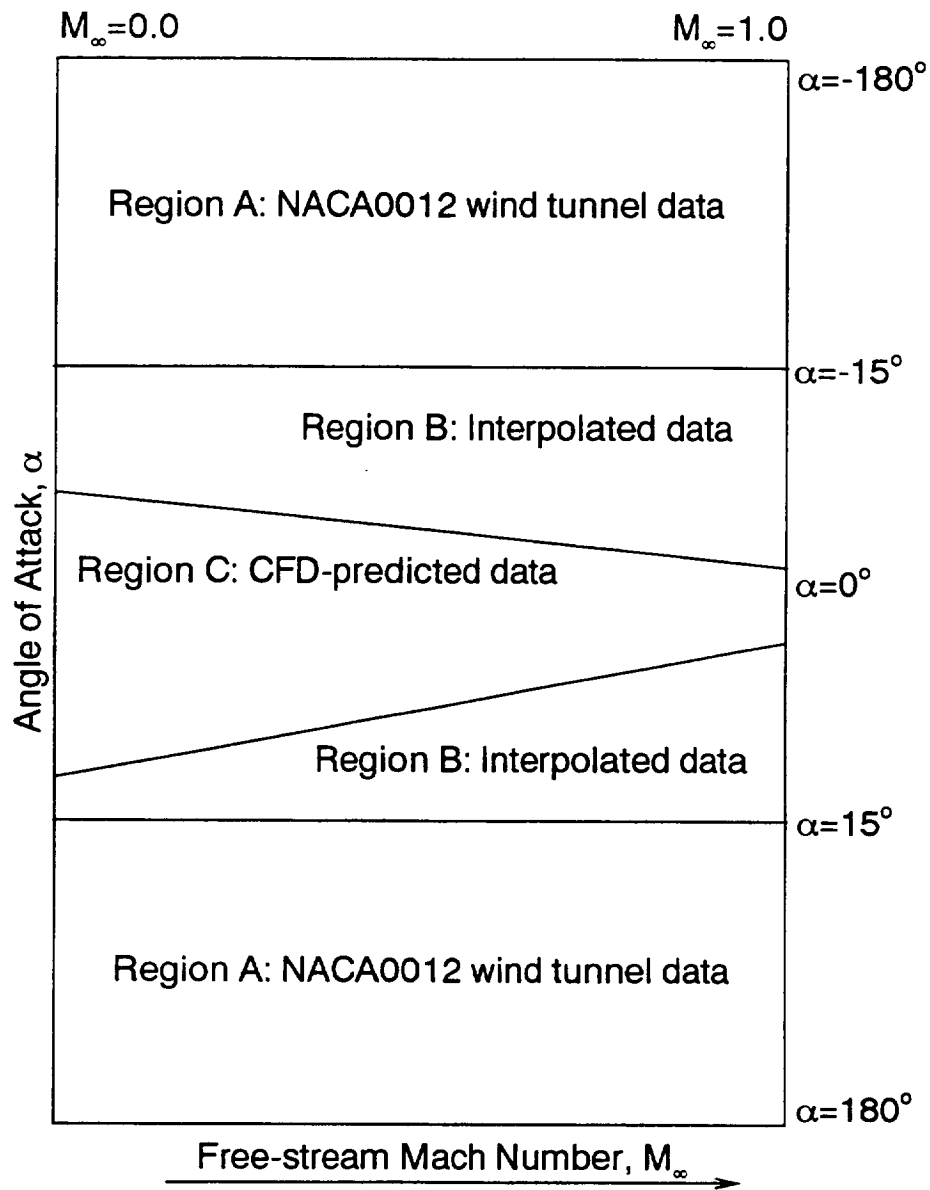


Figure 2. Sketch illustrating the various regions of a C-81 table.

```

conner.larc.nasa.gov> hygrid
input doc file name                hh02.doc
input binary grid file name        grid.dat
do you have body coordinates on file (y/n)? y
input body file name                hh02.in
body file was user input hh02.in
with 79 points
****airfoil lower surface****
input x location, min arclength spacing, (-1 -1 to continue)
1.0 0.0075
input x location, min arclength spacing, (-1 -1 to continue)
0.0 0.0075
input x location, min arclength spacing, (-1 -1 to continue)
-1 -1
****airfoil upper surface****
input x location, min arclength spacing, (-1 -1 to continue)
1.0 0.0075
input x location, min arclength spacing, (-1 -1 to continue)
-1 -1
input number of points for the interval x=1.0000 to x=0.0000
arclength = 1.039867 on the lower surface
75
input number of points for the interval x=0.0000 to x=1.0000
arclength = 1.026164 on the upper surface
75
do you wish tensioned spline fits (y/n)? n
*****outer domain limits*****
input distance to outer boundary 6
input number of points in the wake region 31
trailing edge slope = 0.176327195104507
do you wish to change slope estimation <y/n>? n
jmax = 211
jtail1 = 31
jtail2 = 181
input kmax,normal wall spacing 50 0.00001
.
.
.
conner.larc.nasa.gov>

```

Figure 3. A sample interactive session for generating grid.

1.00000000	0.00881500
0.95000000	0.00125000
0.89920000	-0.00319000
0.85710000	-0.00252000
0.80950000	-0.00190000
0.76190000	-0.00176000
0.71430000	-0.00281000
0.66700000	-0.00500000
0.61900000	-0.00819000
0.57140000	-0.01157000
0.52380000	-0.01500000
0.47620000	-0.01814000
0.42860000	-0.02100000
0.38100000	-0.02333000
0.33330000	-0.02500000
0.28570000	-0.02595000
0.23810000	-0.02605000
0.19050000	-0.02680000
0.16670000	-0.02579000
0.14290000	-0.02525000
0.13100000	-0.02487000
0.11900000	-0.02439000
0.10710000	-0.02382000
0.09520000	-0.02313000
0.08330000	-0.02230000
0.07140000	-0.02130000
0.05950000	-0.02010000
0.04760000	-0.01862000
0.03570000	-0.01692000
0.02380000	-0.01473000
0.01900000	-0.01360000
0.01430000	-0.01217000
0.01190000	-0.01135000
0.00950000	-0.01038000
0.00710000	-0.00920000
0.00480000	-0.00773000
0.00360000	-0.00681000
0.00240000	-0.00567000
0.00120000	-0.00411000
0.00000000	0.00000000
0.00120000	0.00445000
0.00240000	0.00665000

Figure 4. A sample input file for grid, hh02.in.

0.00360000	0.00842000
0.00480000	0.00995000
0.00710000	0.01259000
0.00950000	0.01487000
0.01190000	0.01690000
0.01430000	0.01876000
0.01900000	0.02205000
0.02380000	0.02495000
0.03570000	0.03105000
0.04760000	0.03605000
0.05950000	0.04030000
0.07140000	0.04397000
0.08330000	0.04719000
0.09520000	0.05003000
0.10710000	0.05257000
0.11900000	0.05483000
0.13100000	0.05686000
0.14290000	0.05868000
0.16670000	0.06178000
0.19050000	0.06426000
0.23810000	0.06773000
0.28570000	0.06963000
0.33330000	0.07030000
0.38100000	0.07033000
0.42860000	0.06890000
0.47620000	0.06624000
0.52380000	0.06233000
0.57140000	0.05757000
0.61900000	0.05171000
0.66700000	0.04495000
0.71430000	0.03710000
0.76190000	0.02838000
0.80950000	0.01967000
0.85710000	0.01095000
0.89920000	0.00319000
0.95000000	0.00763000
1.00000000	0.00881500

(Figure 4. Continued.)

```

$INPUTS FSMACH= 0.30000000000000007, ALPHA= 4., RE= 3000000, METH=3,
JMAX= 211, KMAX= 50, JTAIL1= 31, JTAIL2= 181,
TRANSLO= 0.0, TRANSUP= 0.0, RESTART=FALSE,
DIS4X= 0.64, DIS4Y= 0.64, DIS2X= 0., DIS2Y= 0.,
IPRINT=10, IREAD= 2, STORE= TRUE, ISPEC=1,
BCAIRF= TRUE, CIRCUL= FALSE, PERIODIC= FALSE,
VISCOUS= TRUE, TURBULNT= TRUE, VISXI= TRUE,
NP= 100000, NPCP=100000, JACDT=1, ISAVE=10000 $
$FINFO XLIM=0.75, XHINGE=0.75, IFLAG=1,
FANG=0. $
ISEQUAL IF ISEQUAL GT 1, DTISEQ : II=1, ISEQUAL
3
JMXI, KMXI, IENDS, DTISEQ, DTMINS
211, 50, 350, 1.0, 0.0
211, 50, 500, 3.0, 0.0
211, 50, 750, 5.0, 0.0

```

Figure 5. A sample input file for CFD flow solver.

NMACH ----- DELTA = DEGREES								
	MACH	ALFA	CL	CD	CM	CLF	CDF	CMF
15								
20	0.2000	-5.0000	-0.5360	0.0250	0.0064	-0.0760	0.0036	0.0095
	0.2000	-4.0000	-0.4378	0.0208	0.0075	-0.0736	0.0025	0.0094
	0.2000	-3.0000	-0.3357	0.0177	0.0085	-0.0707	0.0014	0.0093
	0.2000	-2.0000	-0.2305	0.0153	0.0092	-0.0673	0.0004	0.0090
	0.2000	-1.0000	-0.1230	0.0136	0.0098	-0.0633	-0.0005	0.0087
	0.2000	0.0000	-0.0138	0.0125	0.0100	-0.0590	-0.0013	0.0084
	0.2000	1.0000	0.0976	0.0120	0.0099	-0.0540	-0.0020	0.0079
	0.2000	2.0000	0.2081	0.0121	0.0100	-0.0491	-0.0024	0.0075
	0.2000	3.0000	0.3193	0.0127	0.0099	-0.0439	-0.0027	0.0070
	0.2000	4.0000	0.4306	0.0138	0.0095	-0.0383	-0.0028	0.0065
	0.2000	5.0000	0.5414	0.0154	0.0090	-0.0324	-0.0027	0.0059
	0.2000	6.0000	0.6515	0.0176	0.0083	-0.0261	-0.0023	0.0052
	0.2000	7.0000	0.7593	0.0205	0.0077	-0.0198	-0.0017	0.0046
	0.2000	8.0000	0.8645	0.0242	0.0069	-0.0131	-0.0008	0.0039
	0.2000	9.0000	0.9658	0.0286	0.0060	-0.0061	0.0005	0.0031
	0.2000	10.0000	1.0614	0.0340	0.0052	0.0013	0.0022	0.0022
	0.2000	11.0000	1.1497	0.0405	0.0043	0.0091	0.0044	0.0013
	0.2000	12.0000	1.2282	0.0483	0.0031	0.0175	0.0072	0.0003
	0.2000	13.0000	1.2934	0.0578	0.0013	0.0268	0.0109	-0.0008
	0.2000	14.0000	1.3413	0.0694	-0.0016	0.0371	0.0154	-0.0020
20								
	0.3000	-5.0000	-0.5466	0.0239	0.0059	-0.0775	0.0034	0.0097
	0.3000	-4.0000	-0.4467	0.0197	0.0074	-0.0753	0.0023	0.0096
	0.3000	-3.0000	-0.3426	0.0165	0.0086	-0.0725	0.0012	0.0095
	0.3000	-2.0000	-0.2352	0.0141	0.0094	-0.0690	0.0002	0.0093
	0.3000	-1.0000	-0.1256	0.0125	0.0100	-0.0650	-0.0008	0.0090
	0.3000	0.0000	-0.0142	0.0116	0.0103	-0.0606	-0.0015	0.0086
	0.3000	1.0000	0.0999	0.0112	0.0101	-0.0554	-0.0022	0.0081
	0.3000	2.0000	0.2125	0.0113	0.0102	-0.0505	-0.0027	0.0077
	0.3000	3.0000	0.3261	0.0121	0.0100	-0.0452	-0.0031	0.0072
	0.3000	4.0000	0.4398	0.0133	0.0096	-0.0395	-0.0032	0.0067
	0.3000	5.0000	0.5532	0.0150	0.0091	-0.0335	-0.0031	0.0061
	0.3000	6.0000	0.6655	0.0174	0.0086	-0.0274	-0.0027	0.0054
	0.3000	7.0000	0.7760	0.0204	0.0080	-0.0209	-0.0021	0.0048
	0.3000	8.0000	0.8839	0.0242	0.0074	-0.0140	-0.0011	0.0040
	0.3000	9.0000	0.9875	0.0290	0.0067	-0.0067	0.0002	0.0032
	0.3000	10.0000	1.0843	0.0348	0.0061	0.0013	0.0021	0.0023
	0.3000	11.0000	1.1724	0.0419	0.0055	0.0092	0.0044	0.0014
	0.3000	12.0000	1.2472	0.0508	0.0045	0.0184	0.0076	0.0003
	0.3000	13.0000	1.3034	0.0619	0.0025	0.0287	0.0118	-0.0010
	0.3000	14.0000	1.3224	0.0749	0.0005	0.0388	0.0166	-0.0023
20								
	0.4000	-5.0000	-0.5573	0.0249	0.0042	-0.0780	0.0030	0.0097
	0.4000	-4.0000	-0.4578	0.0197	0.0064	-0.0767	0.0020	0.0098
	0.4000	-3.0000	-0.3517	0.0160	0.0080	-0.0743	0.0009	0.0097
	0.4000	-2.0000	-0.2415	0.0135	0.0092	-0.0710	-0.0001	0.0095
	0.4000	-1.0000	-0.1284	0.0119	0.0100	-0.0671	-0.0010	0.0092
	0.4000	0.0000	-0.0134	0.0109	0.0104	-0.0626	-0.0019	0.0089
	0.4000	1.0000	0.1049	0.0106	0.0101	-0.0572	-0.0026	0.0084
	0.4000	2.0000	0.2213	0.0109	0.0102	-0.0522	-0.0031	0.0080
	0.4000	3.0000	0.3389	0.0118	0.0100	-0.0466	-0.0034	0.0074
	0.4000	4.0000	0.4565	0.0131	0.0097	-0.0408	-0.0035	0.0069
	0.4000	5.0000	0.5736	0.0151	0.0094	-0.0349	-0.0034	0.0063
	0.4000	6.0000	0.6902	0.0177	0.0090	-0.0286	-0.0031	0.0056
	0.4000	7.0000	0.8051	0.0210	0.0087	-0.0218	-0.0024	0.0049
	0.4000	8.0000	0.9173	0.0252	0.0084	-0.0145	-0.0014	0.0041

Figure 6. A sample "LOADS.TBL" file.

	0.4000	9.0000	1.0245	0.0304	0.0084	-0.0069	0.0001	0.0033
	0.4000	10.0000	1.1231	0.0371	0.0084	0.0017	0.0022	0.0023
	0.4000	11.0000	1.2071	0.0456	0.0085	0.0108	0.0050	0.0012
	0.4000	12.0000	1.2705	0.0566	0.0076	0.0218	0.0090	-0.0001
	0.4000	13.0000	1.2904	0.0704	0.0059	0.0333	0.0141	-0.0016
19	0.4000	14.0000	1.2735	0.1065	-0.0376	0.0883	0.0315	-0.0100
	0.4500	-5.0000	-0.5594	0.0270	0.0023	-0.0772	0.0028	0.0096
	0.4500	-4.0000	-0.4643	0.0202	0.0052	-0.0772	0.0018	0.0098
	0.4500	-3.0000	-0.3575	0.0160	0.0074	-0.0752	0.0007	0.0098
	0.4500	-2.0000	-0.2455	0.0133	0.0089	-0.0722	-0.0003	0.0097
	0.4500	-1.0000	-0.1301	0.0116	0.0098	-0.0683	-0.0012	0.0094
	0.4500	0.0000	-0.0125	0.0107	0.0103	-0.0637	-0.0020	0.0090
	0.4500	1.0000	0.1087	0.0104	0.0100	-0.0582	-0.0028	0.0086
	0.4500	2.0000	0.2279	0.0107	0.0100	-0.0531	-0.0033	0.0081
	0.4500	3.0000	0.3479	0.0117	0.0100	-0.0476	-0.0036	0.0076
	0.4500	4.0000	0.4683	0.0132	0.0097	-0.0418	-0.0037	0.0070
	0.4500	5.0000	0.5886	0.0153	0.0095	-0.0357	-0.0036	0.0064
	0.4500	6.0000	0.7084	0.0180	0.0094	-0.0292	-0.0033	0.0057
	0.4500	7.0000	0.8266	0.0215	0.0094	-0.0223	-0.0026	0.0050
	0.4500	8.0000	0.9422	0.0260	0.0096	-0.0149	-0.0015	0.0042
	0.4500	9.0000	1.0525	0.0315	0.0102	-0.0068	0.0000	0.0033
	0.4500	10.0000	1.1537	0.0386	0.0112	0.0019	0.0022	0.0023
	0.4500	11.0000	1.2333	0.0485	0.0122	0.0125	0.0056	0.0010
	0.4500	12.0000	1.2639	0.0636	0.0104	0.0260	0.0110	-0.0006
	0.4500	13.0000	1.2176	0.0811	0.0046	0.0397	0.0173	-0.0026
18	0.5000	-5.0000	-0.5550	0.0315	0.0001	-0.0750	0.0024	0.0093
	0.5000	-4.0000	-0.4691	0.0216	0.0033	-0.0769	0.0015	0.0098
	0.5000	-3.0000	-0.3645	0.0162	0.0064	-0.0762	0.0006	0.0100
	0.5000	-2.0000	-0.2502	0.0132	0.0084	-0.0734	-0.0004	0.0098
	0.5000	-1.0000	-0.1319	0.0114	0.0096	-0.0696	-0.0014	0.0096
	0.5000	0.0000	-0.0075	0.0104	0.0094	-0.0641	-0.0023	0.0091
	0.5000	1.0000	0.1135	0.0102	0.0098	-0.0594	-0.0030	0.0087
	0.5000	2.0000	0.2361	0.0106	0.0099	-0.0542	-0.0035	0.0083
	0.5000	3.0000	0.3597	0.0116	0.0099	-0.0486	-0.0039	0.0077
	0.5000	4.0000	0.4838	0.0133	0.0098	-0.0427	-0.0040	0.0072
	0.5000	5.0000	0.6080	0.0156	0.0098	-0.0365	-0.0039	0.0065
	0.5000	6.0000	0.7321	0.0185	0.0100	-0.0299	-0.0035	0.0059
	0.5000	7.0000	0.8549	0.0223	0.0106	-0.0229	-0.0028	0.0051
	0.5000	8.0000	0.9760	0.0270	0.0117	-0.0151	-0.0017	0.0043
	0.5000	9.0000	1.0913	0.0331	0.0141	-0.0069	-0.0001	0.0034
	0.5000	10.0000	1.1800	0.0434	0.0164	0.0043	0.0030	0.0020
	0.5000	11.0000	1.2248	0.0585	0.0164	0.0177	0.0079	0.0004
	0.5000	12.0000	1.2059	0.0737	0.0152	0.0284	0.0130	-0.0010
17	0.5500	-5.0000	-0.5507	0.0376	-0.0011	-0.0730	0.0021	0.0089
	0.5500	-4.0000	-0.4688	0.0249	0.0002	-0.0749	0.0011	0.0095
	0.5500	-3.0000	-0.3708	0.0171	0.0046	-0.0765	0.0003	0.0100
	0.5500	-2.0000	-0.2557	0.0132	0.0075	-0.0748	-0.0006	0.0100
	0.5500	-1.0000	-0.1339	0.0112	0.0091	-0.0711	-0.0016	0.0098
	0.5500	0.0000	-0.0047	0.0102	0.0089	-0.0655	-0.0025	0.0093
	0.5500	1.0000	0.1201	0.0100	0.0095	-0.0608	-0.0032	0.0089
	0.5500	2.0000	0.2470	0.0105	0.0097	-0.0555	-0.0038	0.0085
	0.5500	3.0000	0.3751	0.0117	0.0098	-0.0499	-0.0041	0.0079
	0.5500	4.0000	0.5040	0.0136	0.0098	-0.0438	-0.0042	0.0073
	0.5500	5.0000	0.6337	0.0161	0.0102	-0.0374	-0.0041	0.0067
	0.5500	6.0000	0.7637	0.0193	0.0111	-0.0307	-0.0038	0.0060
	0.5500	7.0000	0.8937	0.0235	0.0132	-0.0235	-0.0031	0.0052
	0.5500	8.0000	1.0168	0.0303	0.0164	-0.0143	-0.0015	0.0042

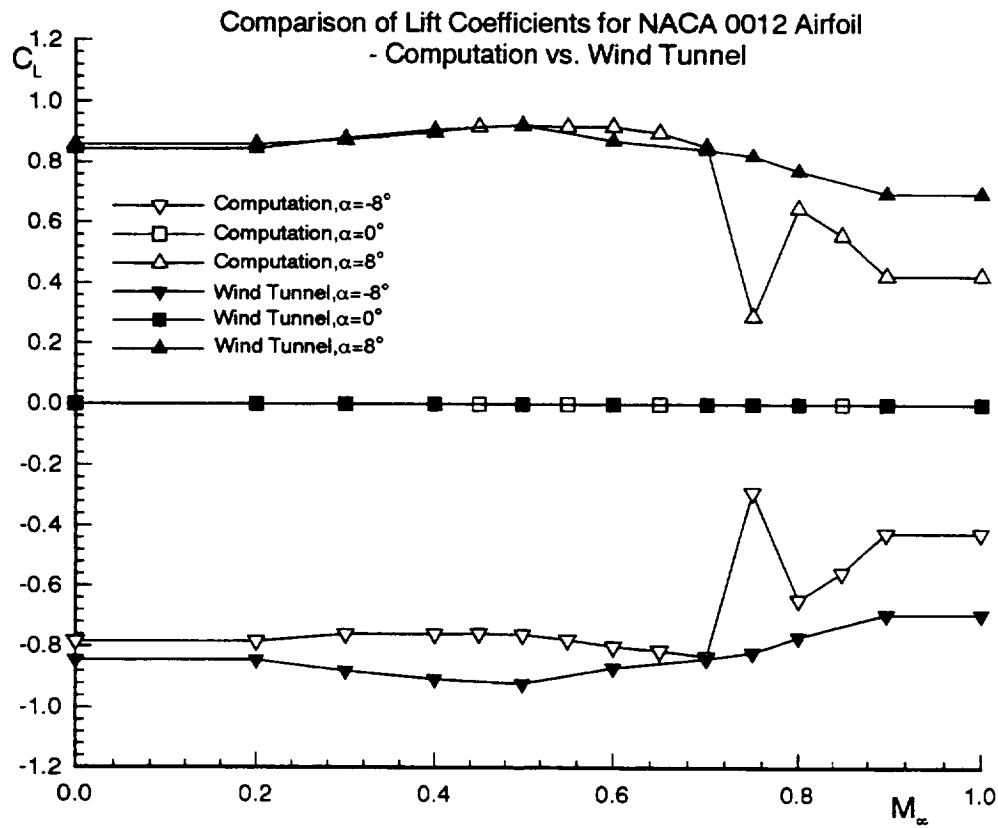
(Figure 6. Continued.)

15	0.5500	9.0000	1.1124	0.0419	0.0195	-0.0032	0.0012	0.0029
	0.5500	10.0000	1.1744	0.0575	0.0211	0.0087	0.0050	0.0015
	0.5500	11.0000	1.1760	0.0739	0.0186	0.0215	0.0102	-0.0001
15	0.6000	-4.0000	-0.4741	0.0285	-0.0041	-0.0739	0.0008	0.0093
	0.6000	-3.0000	-0.3758	0.0190	0.0011	-0.0759	0.0000	0.0099
	0.6000	-2.0000	-0.2626	0.0134	0.0060	-0.0761	-0.0009	0.0102
	0.6000	-1.0000	-0.1358	0.0111	0.0083	-0.0728	-0.0018	0.0100
	0.6000	0.0000	-0.0012	0.0100	0.0083	-0.0671	-0.0027	0.0095
	0.6000	1.0000	0.1289	0.0099	0.0091	-0.0625	-0.0035	0.0092
	0.6000	2.0000	0.2610	0.0106	0.0095	-0.0572	-0.0040	0.0087
	0.6000	3.0000	0.3954	0.0119	0.0096	-0.0513	-0.0044	0.0081
	0.6000	4.0000	0.5313	0.0140	0.0101	-0.0450	-0.0046	0.0075
	0.6000	5.0000	0.6689	0.0169	0.0114	-0.0385	-0.0045	0.0069
	0.6000	6.0000	0.8076	0.0213	0.0142	-0.0310	-0.0040	0.0061
	0.6000	7.0000	0.9358	0.0303	0.0170	-0.0206	-0.0024	0.0049
13	0.6000	8.0000	1.0423	0.0441	0.0191	-0.0106	-0.0004	0.0037
	0.6000	9.0000	1.1153	0.0614	0.0186	0.0014	0.0031	0.0023
	0.6000	10.0000	1.1166	0.0778	0.0146	0.0152	0.0084	0.0006
	0.6500	-4.0000	-0.5122	0.0331	-0.0103	-0.0773	0.0008	0.0098
	0.6500	-3.0000	-0.3954	0.0214	-0.0038	-0.0777	-0.0002	0.0101
	0.6500	-2.0000	-0.2697	0.0143	0.0027	-0.0769	-0.0012	0.0103
	0.6500	-1.0000	-0.1387	0.0110	0.0070	-0.0748	-0.0021	0.0103
	0.6500	0.0000	0.0038	0.0099	0.0073	-0.0690	-0.0030	0.0098
	0.6500	1.0000	0.1413	0.0099	0.0083	-0.0643	-0.0038	0.0094
	0.6500	2.0000	0.2814	0.0107	0.0089	-0.0590	-0.0044	0.0089
	0.6500	3.0000	0.4244	0.0124	0.0095	-0.0530	-0.0048	0.0084
	0.6500	4.0000	0.5716	0.0150	0.0112	-0.0464	-0.0049	0.0077
11	0.6500	5.0000	0.7192	0.0212	0.0133	-0.0378	-0.0045	0.0068
	0.6500	6.0000	0.8563	0.0331	0.0131	-0.0278	-0.0033	0.0056
	0.6500	7.0000	0.9745	0.0499	0.0101	-0.0173	-0.0014	0.0044
	0.6500	8.0000	1.0475	0.0690	0.0046	-0.0034	0.0023	0.0029
	0.7000	-4.0000	-0.5679	0.0419	-0.0149	-0.0787	0.0004	0.0100
	0.7000	-3.0000	-0.4344	0.0260	-0.0101	-0.0804	-0.0004	0.0105
	0.7000	-2.0000	-0.2878	0.0158	-0.0025	-0.0791	-0.0015	0.0106
	0.7000	-1.0000	-0.1429	0.0112	0.0044	-0.0771	-0.0024	0.0106
	0.7000	0.0000	0.0119	0.0099	0.0057	-0.0712	-0.0034	0.0101
	0.7000	1.0000	0.1604	0.0100	0.0070	-0.0664	-0.0042	0.0097
	0.7000	2.0000	0.3130	0.0111	0.0080	-0.0609	-0.0048	0.0092
	0.7000	3.0000	0.4724	0.0145	0.0091	-0.0540	-0.0052	0.0085
10	0.7000	4.0000	0.6366	0.0234	0.0053	-0.0446	-0.0049	0.0074
	0.7000	5.0000	0.7811	0.0392	-0.0040	-0.0333	-0.0037	0.0062
	0.7000	6.0000	0.8873	0.0587	-0.0154	-0.0170	-0.0004	0.0044
	0.7500	-4.0000	-0.6586	0.0595	-0.0002	-0.0773	-0.0003	0.0099
	0.7500	-3.0000	-0.4936	0.0359	-0.0096	-0.0783	-0.0011	0.0103
	0.7500	-2.0000	-0.3185	0.0200	-0.0091	-0.0797	-0.0019	0.0107
	0.7500	-1.0000	-0.1496	0.0118	-0.0012	-0.0793	-0.0029	0.0109
	0.7500	0.0000	0.0290	0.0100	0.0021	-0.0729	-0.0038	0.0103
	0.7500	1.0000	0.1975	0.0106	0.0040	-0.0686	-0.0047	0.0100
	0.7500	2.0000	0.3760	0.0172	-0.0038	-0.0592	-0.0050	0.0089
	0.7500	3.0000	0.5416	0.0312	-0.0191	-0.0471	-0.0043	0.0076
	0.7500	4.0000	0.5486	0.0348	-0.0057	-0.0383	-0.0021	0.0065
8	0.7500	5.0000	0.7026	0.0611	-0.0415	0.0318	0.0155	-0.0016
	0.8000	-3.0000	-0.5783	0.0564	0.0255	-0.0702	-0.0024	0.0093
	0.8000	-2.0000	-0.3753	0.0312	0.0016	-0.0736	-0.0030	0.0099
	0.8000	-1.0000	-0.1637	0.0157	-0.0090	-0.0789	-0.0036	0.0108

(Figure 6. Continued.)

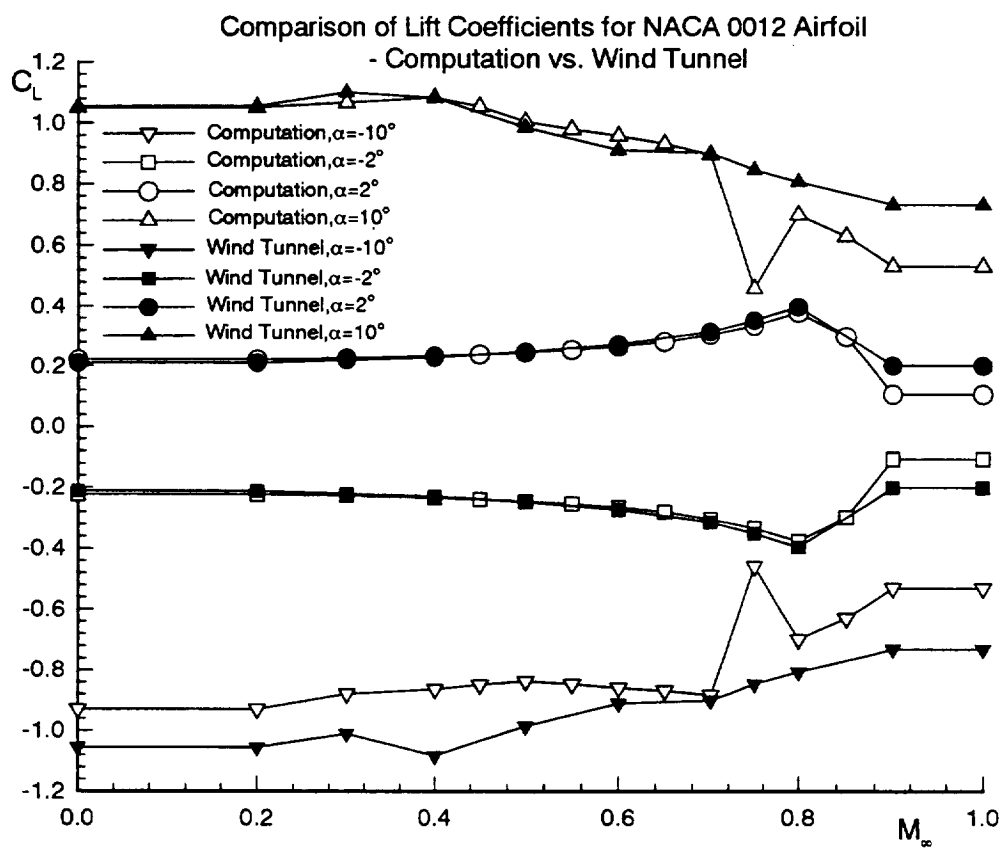
	0.8000	0.0000	0.0559	0.0148	-0.0140	-0.0747	-0.0043	0.0104
	0.8000	1.0000	0.2639	0.0261	-0.0348	-0.0584	-0.0039	0.0087
	0.8000	2.0000	0.4114	0.0408	-0.0606	-0.0155	0.0025	0.0046
	0.8000	3.0000	0.2845	0.0297	0.0022	-0.0450	0.0015	0.0072
4	0.8000	4.0000	0.3871	0.0461	-0.0156	-0.0169	0.0087	0.0051
	0.8500	-1.0000	-0.1683	0.0425	-0.0221	-0.0517	-0.0036	0.0076
	0.8500	0.0000	0.0437	0.0381	-0.0714	-0.0061	0.0027	0.0027
	0.8500	1.0000	0.1155	0.0380	-0.0592	-0.0105	0.0055	0.0035
6	0.8500	2.0000	0.1640	0.0429	-0.0353	-0.0260	0.0092	0.0070
	0.9000	-2.0000	-0.2804	0.0932	0.0063	-0.0413	0.0132	0.0079
	0.9000	-1.0000	-0.2108	0.0796	0.0010	-0.0446	0.0081	0.0057
	0.9000	0.0000	-0.1519	0.0706	0.0046	-0.0442	0.0084	0.0062
	0.9000	1.0000	-0.0697	0.0658	-0.0021	-0.0279	0.0105	0.0058
	0.9000	2.0000	-0.0154	0.0588	-0.0014	0.0058	0.0175	0.0043
	0.9000	3.0000	0.1458	0.0594	-0.0463	0.0413	0.0212	0.0011

(Figure 6. Continued.)



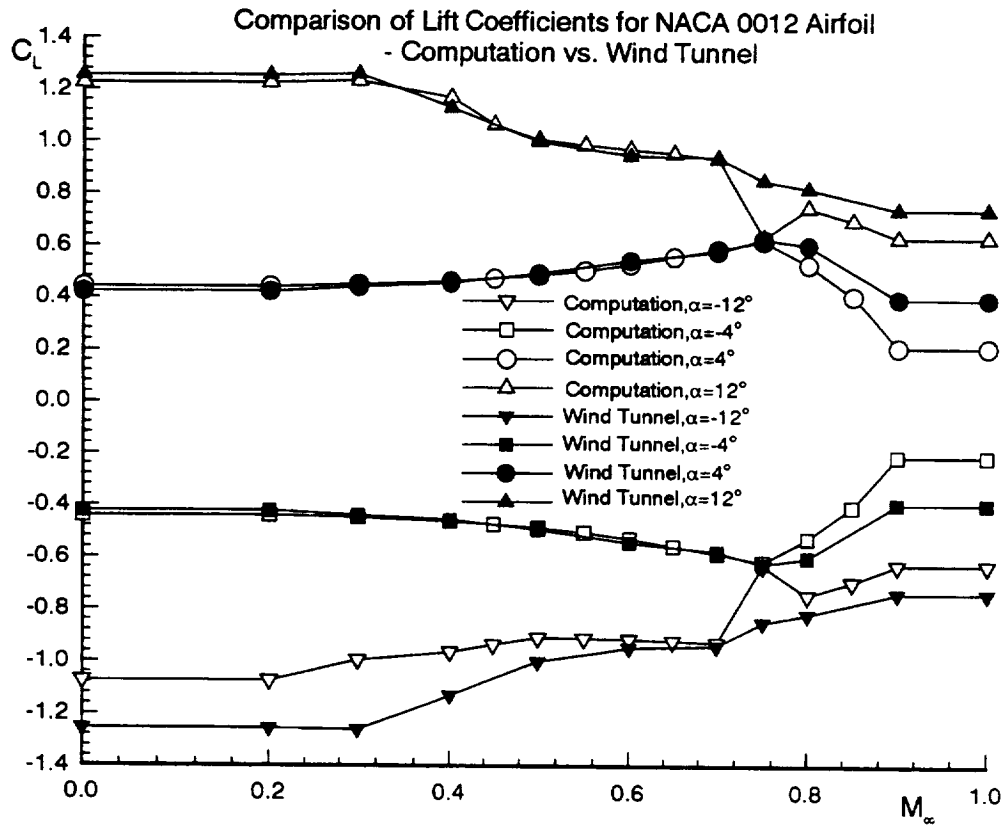
(a) $\alpha = -8^\circ, 0^\circ, 8^\circ$.

Figure 7. Comparison of lift coefficients for NACA 0012 airfoil.



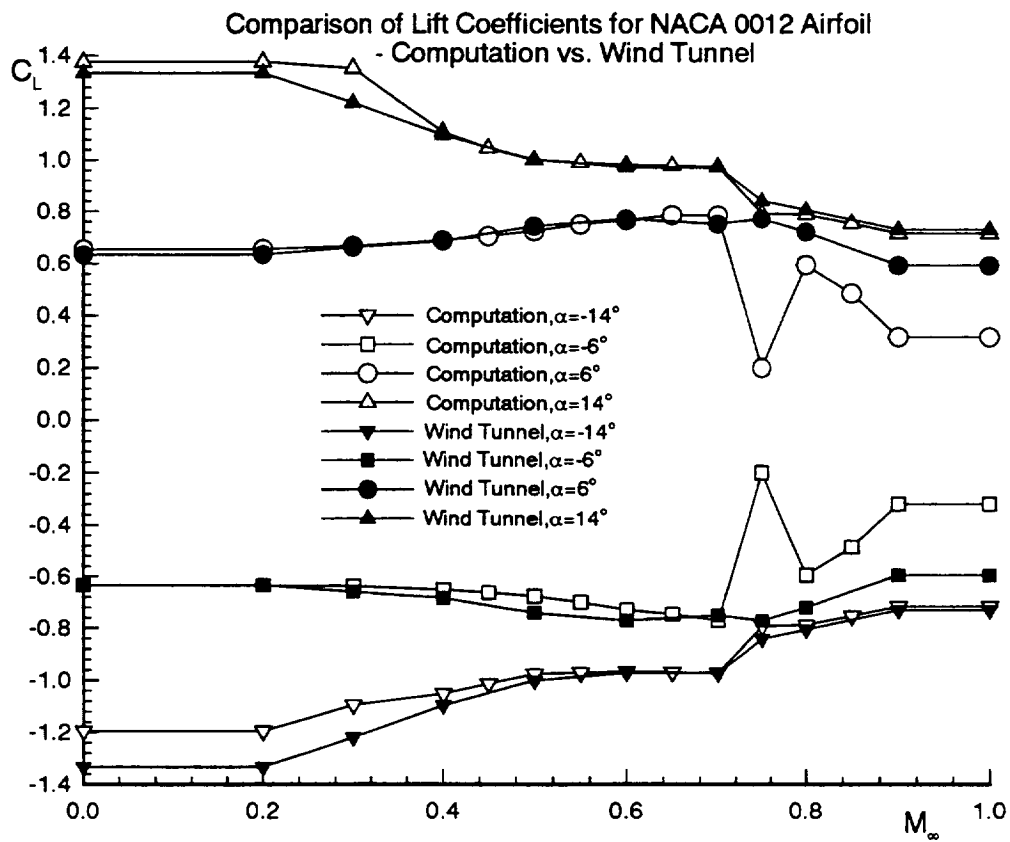
(b) $\alpha = -10^\circ, -2^\circ, 2^\circ, 10^\circ$.

(Figure 7. Continued.)



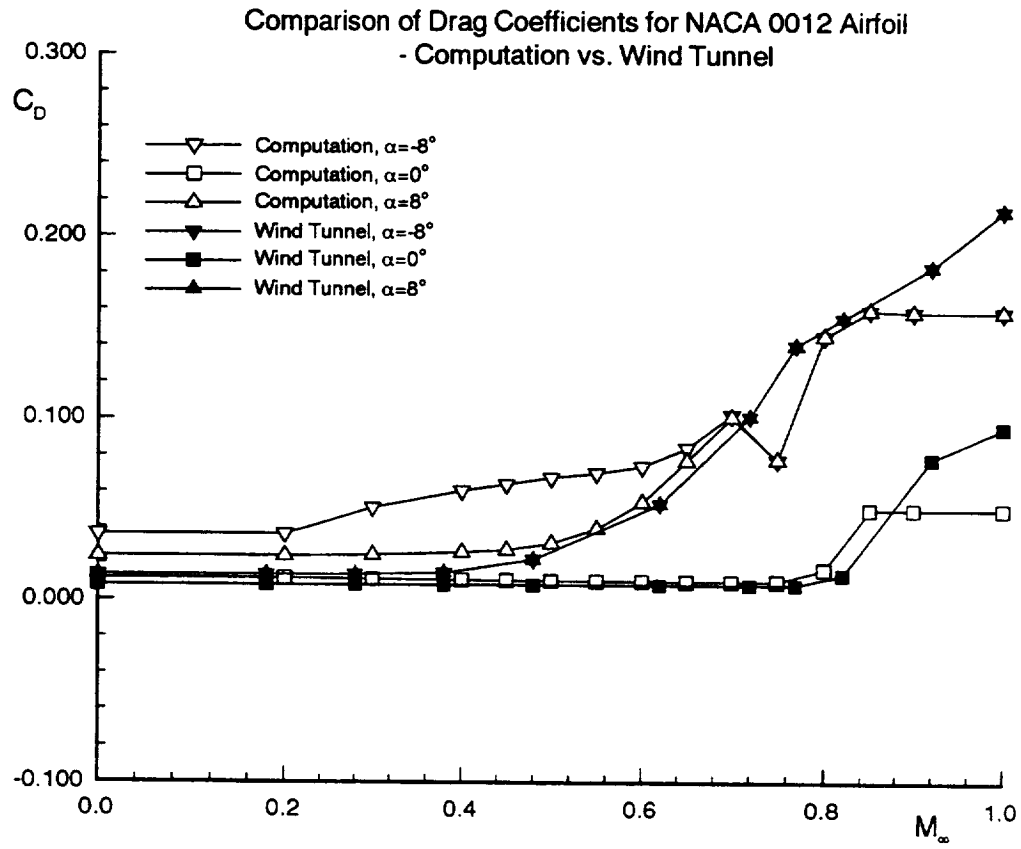
(c) $\alpha = -12^\circ, -4^\circ, 4^\circ, 12^\circ$.

(Figure 7. Continued.)



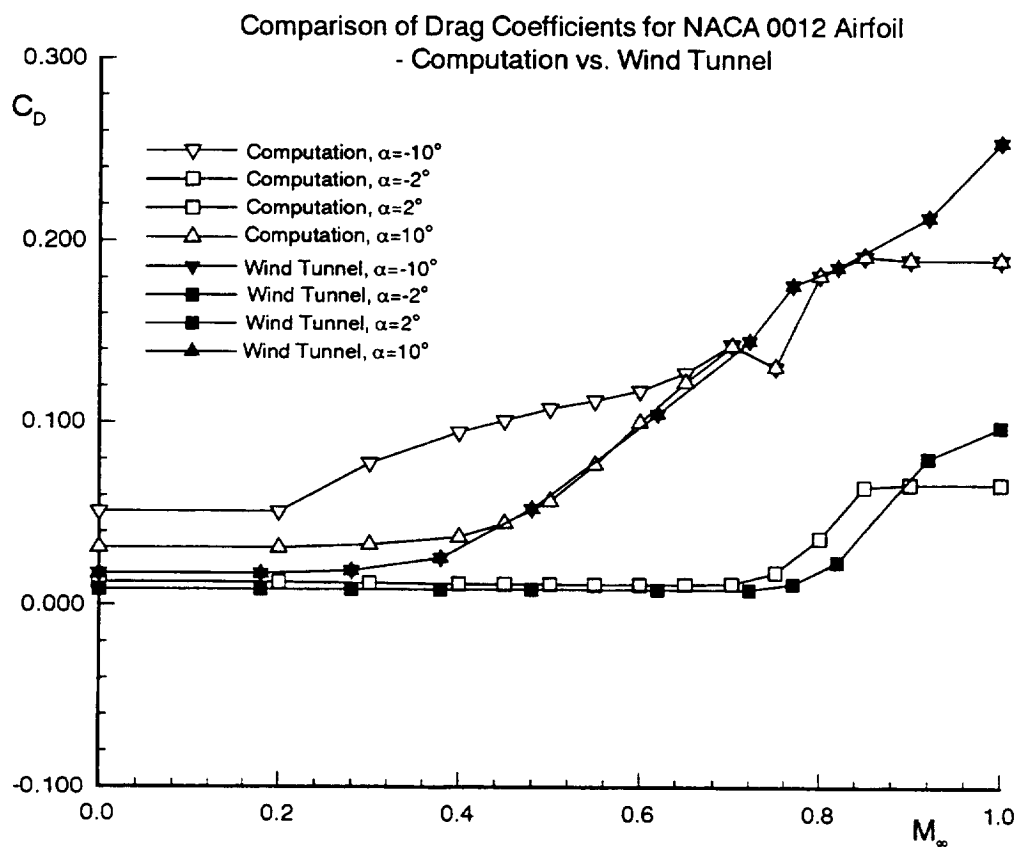
(d) $\alpha = -14^\circ, -6^\circ, 6^\circ, 14^\circ$.

(Figure 7. Continued.)



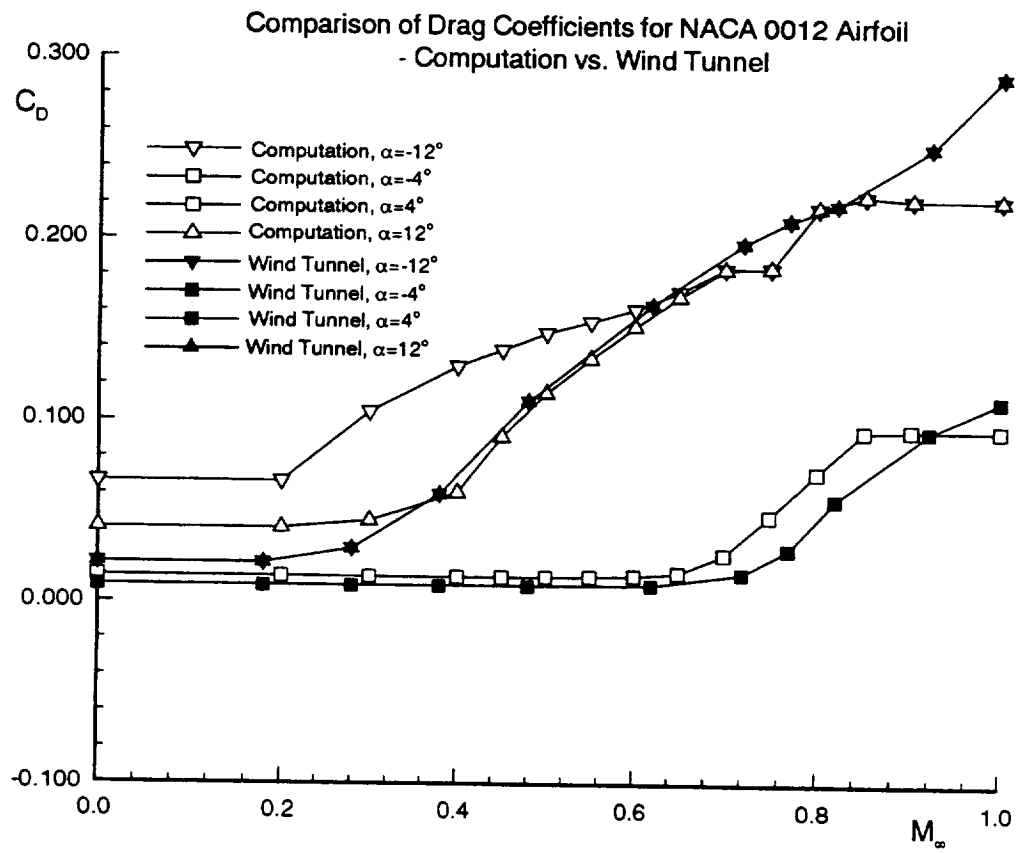
(a) $\alpha = -8^\circ, 0^\circ, 8^\circ$.

Figure 8. Comparison of drag coefficients for NACA 0012 airfoil.



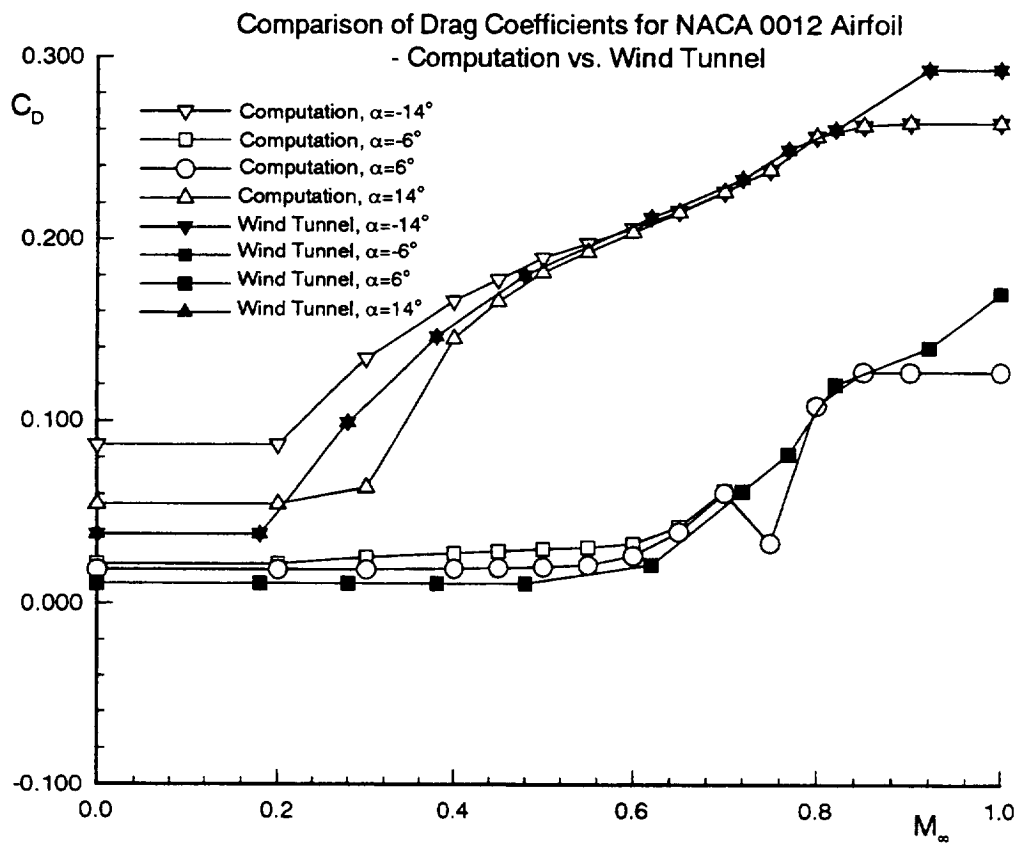
(b) $\alpha = -10^\circ, -2^\circ, 2^\circ, 10^\circ$.

(Figure 8. Continued.)



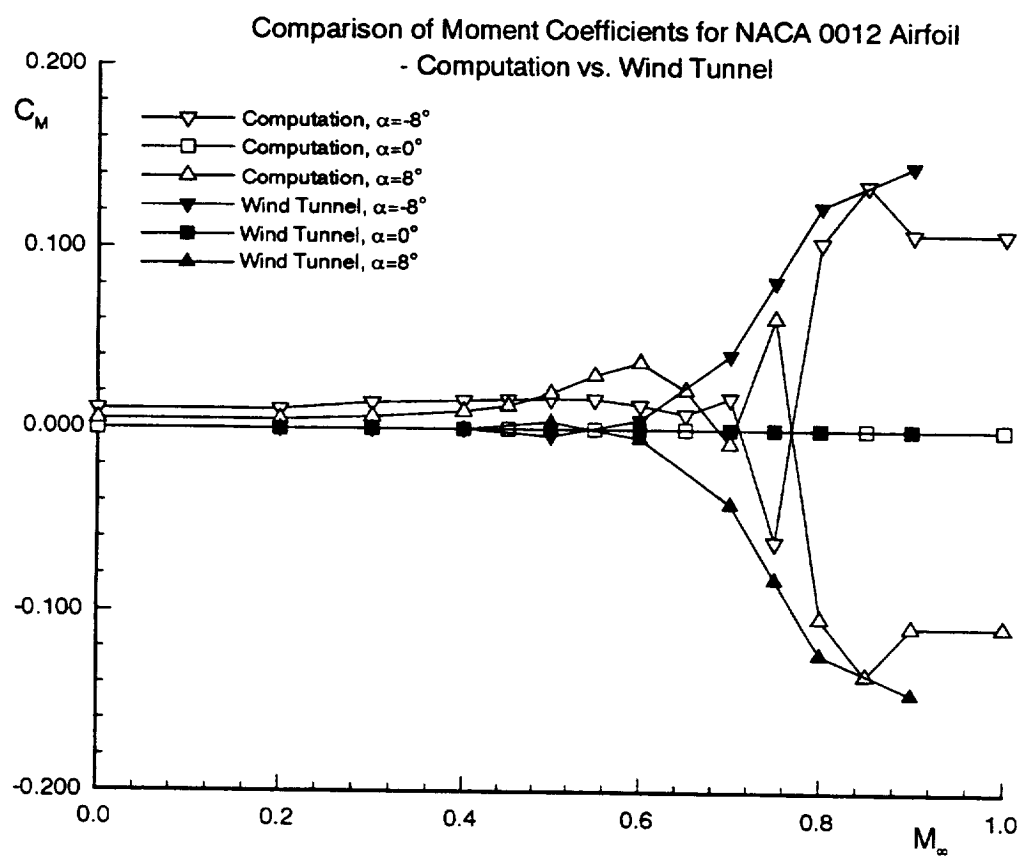
(c) $\alpha = -12^\circ, -4^\circ, 4^\circ, 12^\circ$.

(Figure 8. Continued.)



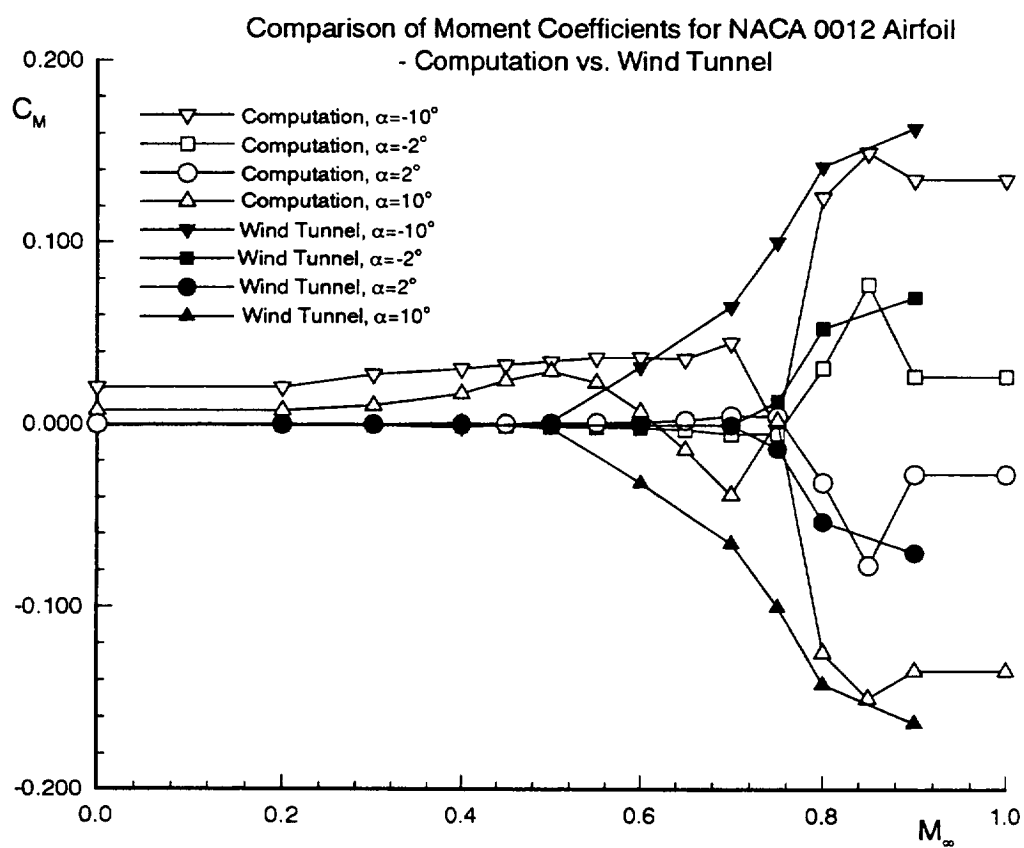
(d) $\alpha = -14^\circ, -6^\circ, 6^\circ, 14^\circ$.

(Figure 8. Continued.)



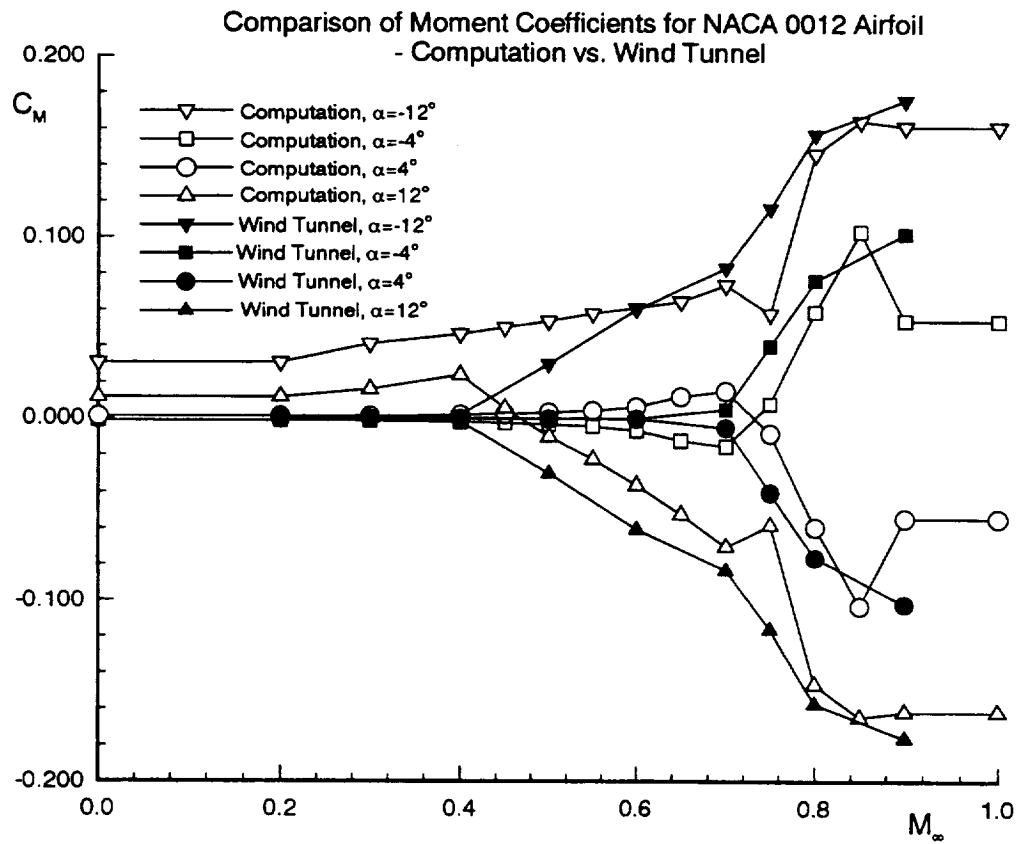
(a) $\alpha = -8^\circ, 0^\circ, 8^\circ$.

Figure 9. Comparison of moment coefficients for NACA 0012 airfoil.



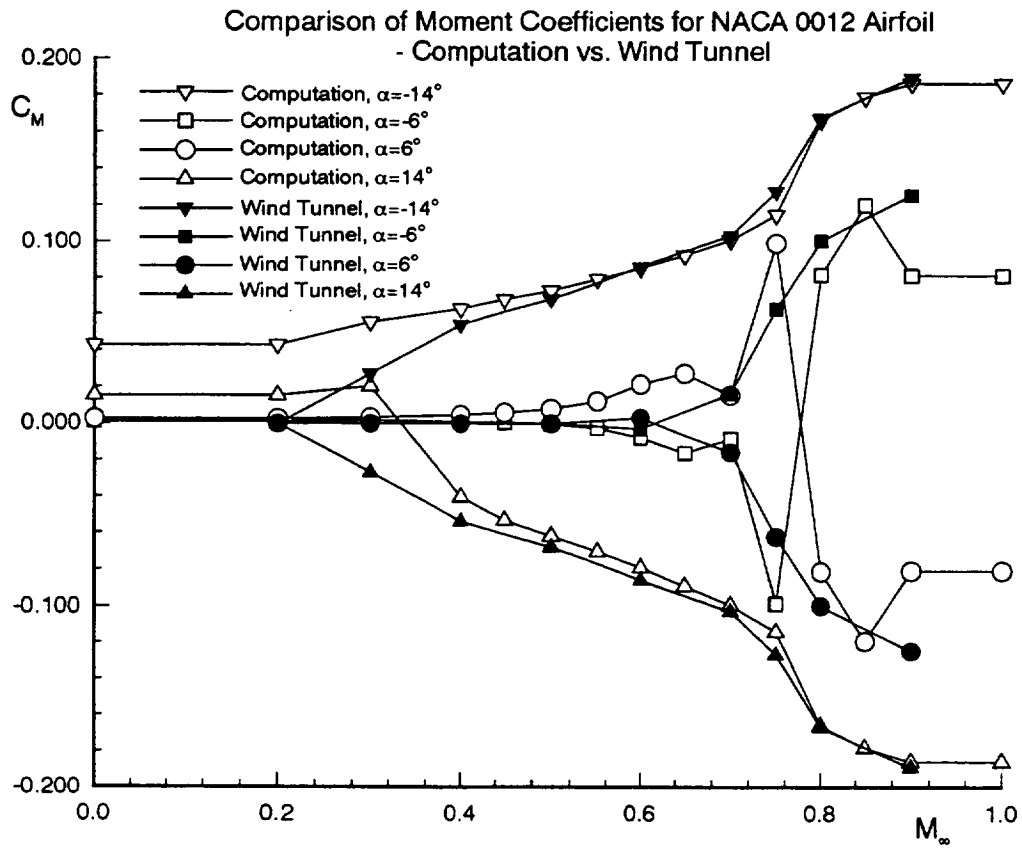
(b) $\alpha = -10^\circ, -2^\circ, 2^\circ, 10^\circ$.

(Figure 9. Continued.)



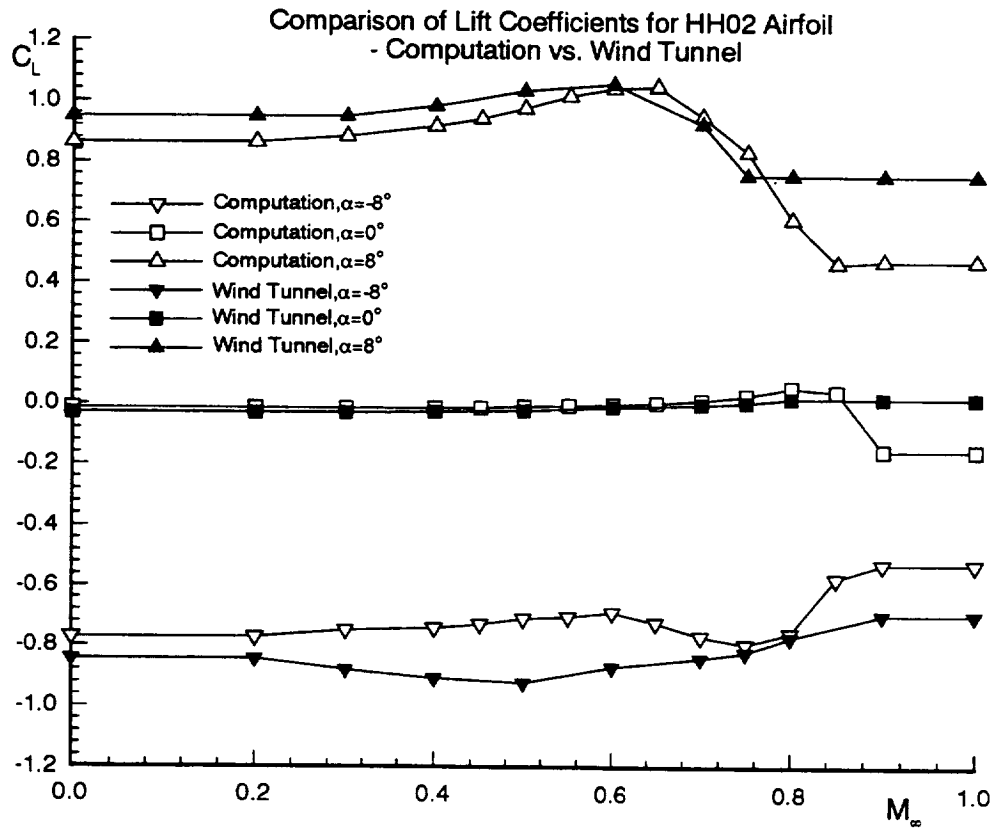
(c) $\alpha = -12^\circ, -4^\circ, 4^\circ, 12^\circ$.

(Figure 9. Continued.)



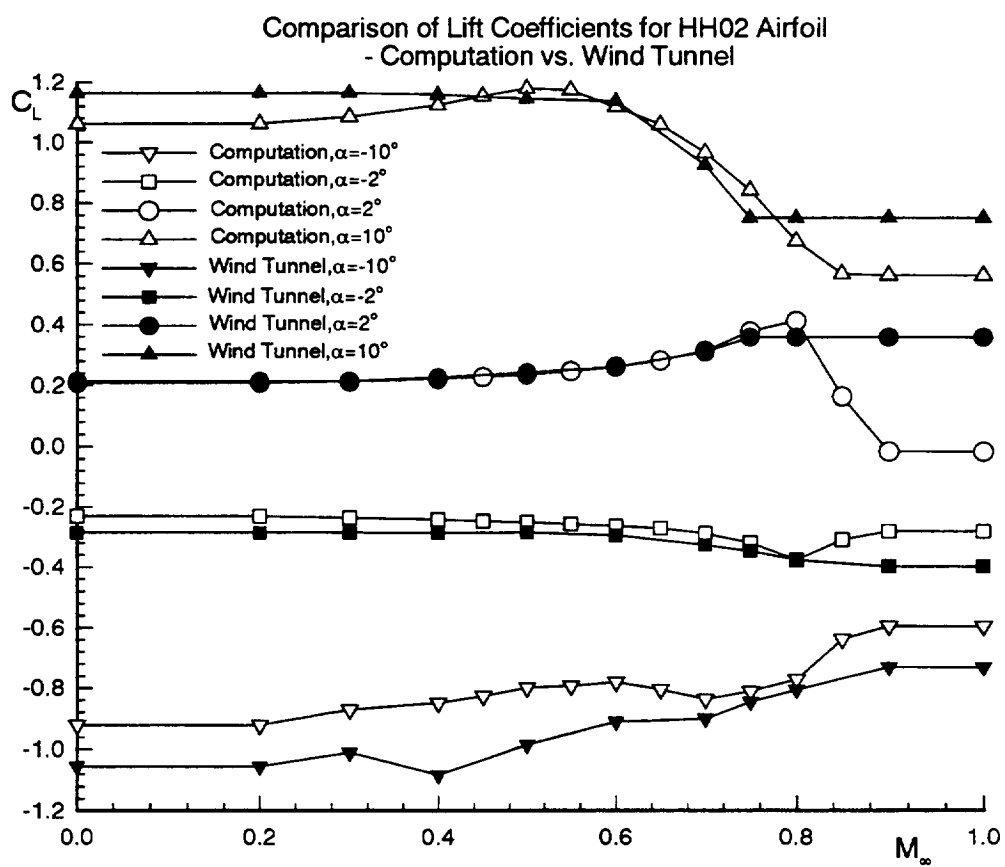
(d) $\alpha = -14^\circ, -6^\circ, 6^\circ, 14^\circ$.

(Figure 9. Continued.)



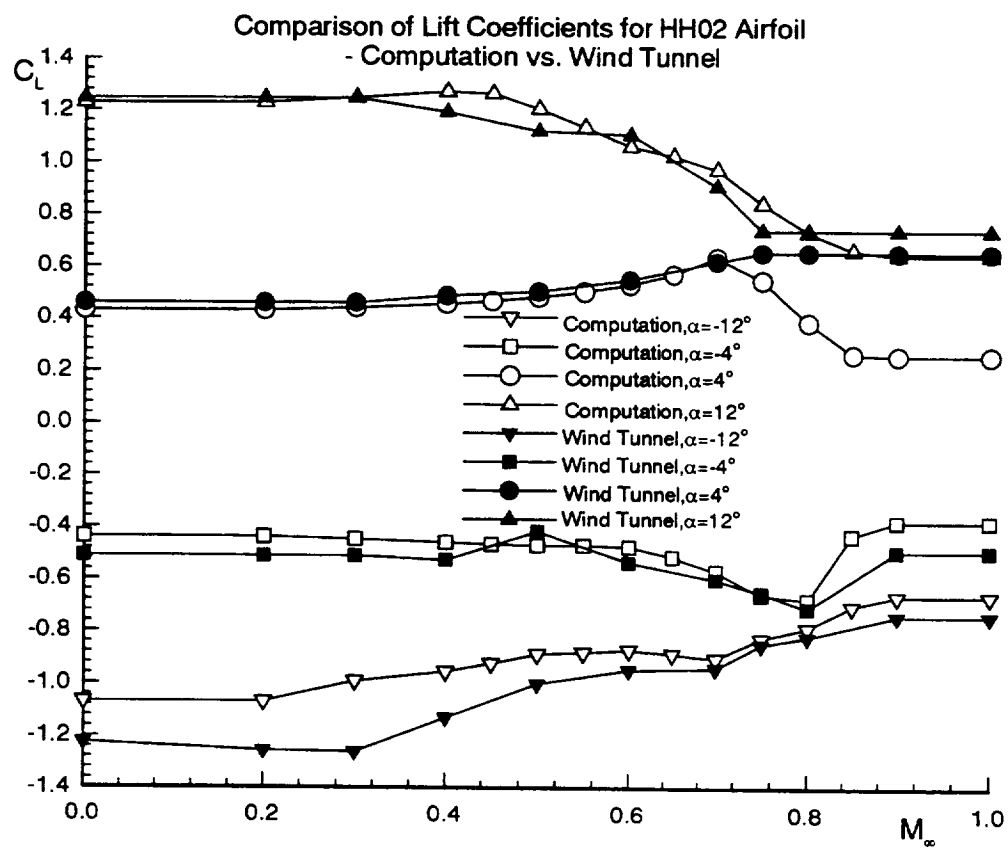
(a) $\alpha = -8^\circ, 0^\circ, 8^\circ$.

Figure 10. Comparison of lift coefficients for HH02 airfoil.



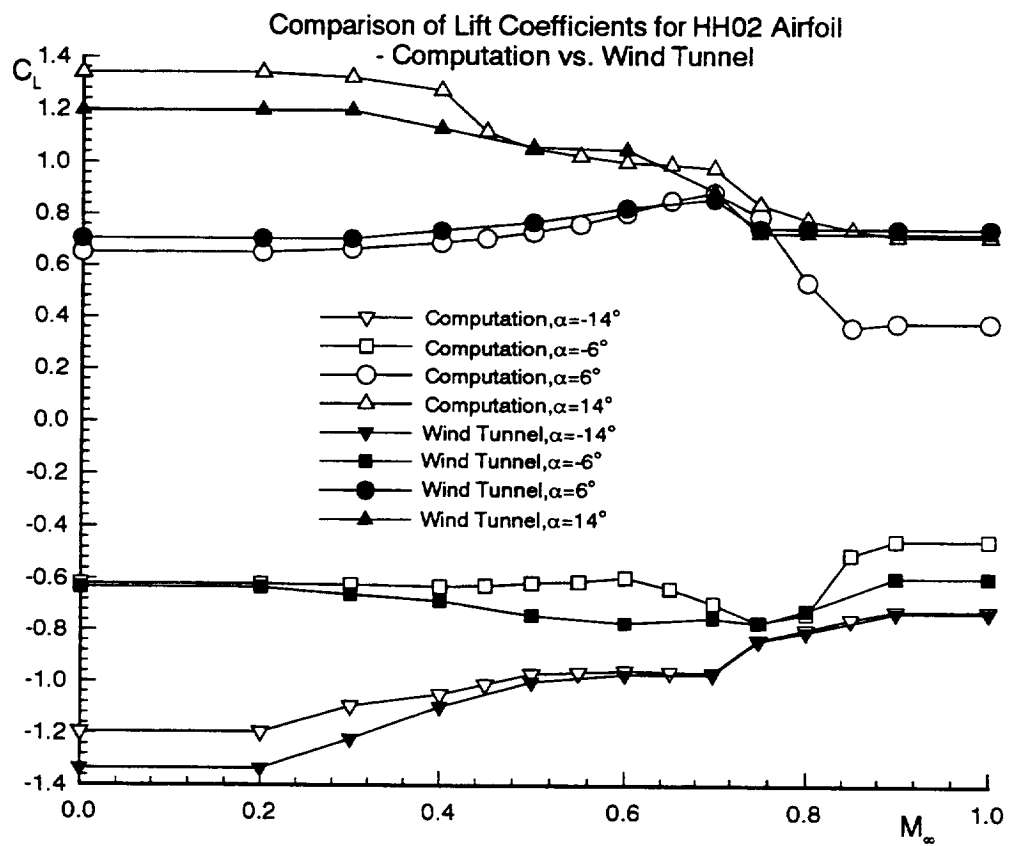
(b) $\alpha = -10^\circ, -2^\circ, 2^\circ, 10^\circ$.

(Figure 10. Continued.)



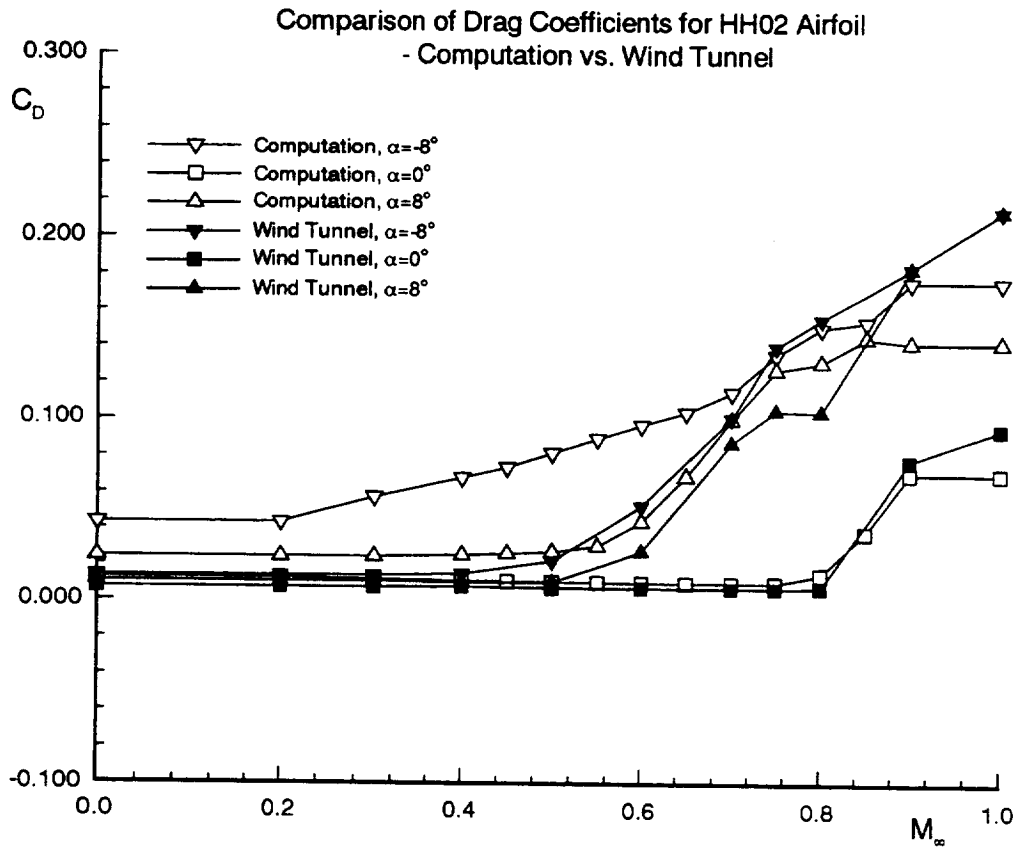
(c) $\alpha = -12^\circ, -4^\circ, 4^\circ, 12^\circ$.

(Figure 10. Continued.)



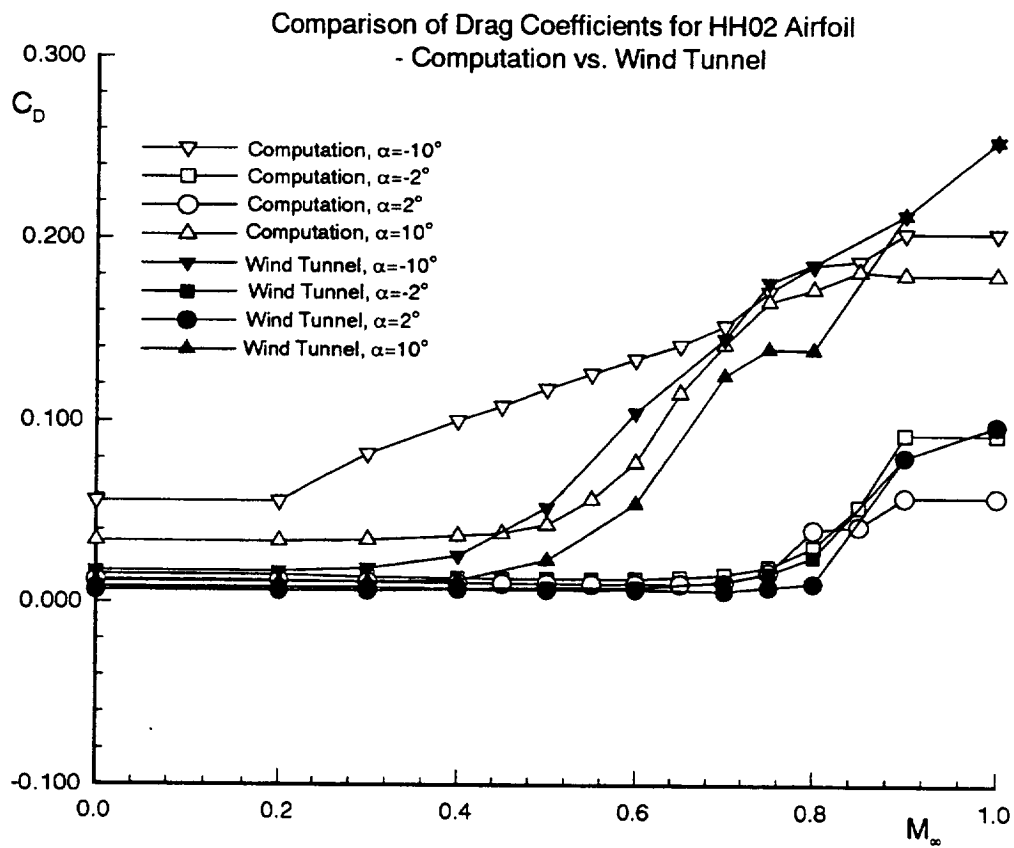
(d) $\alpha = -14^\circ, -6^\circ, 6^\circ, 14^\circ$.

(Figure 10. Continued.)



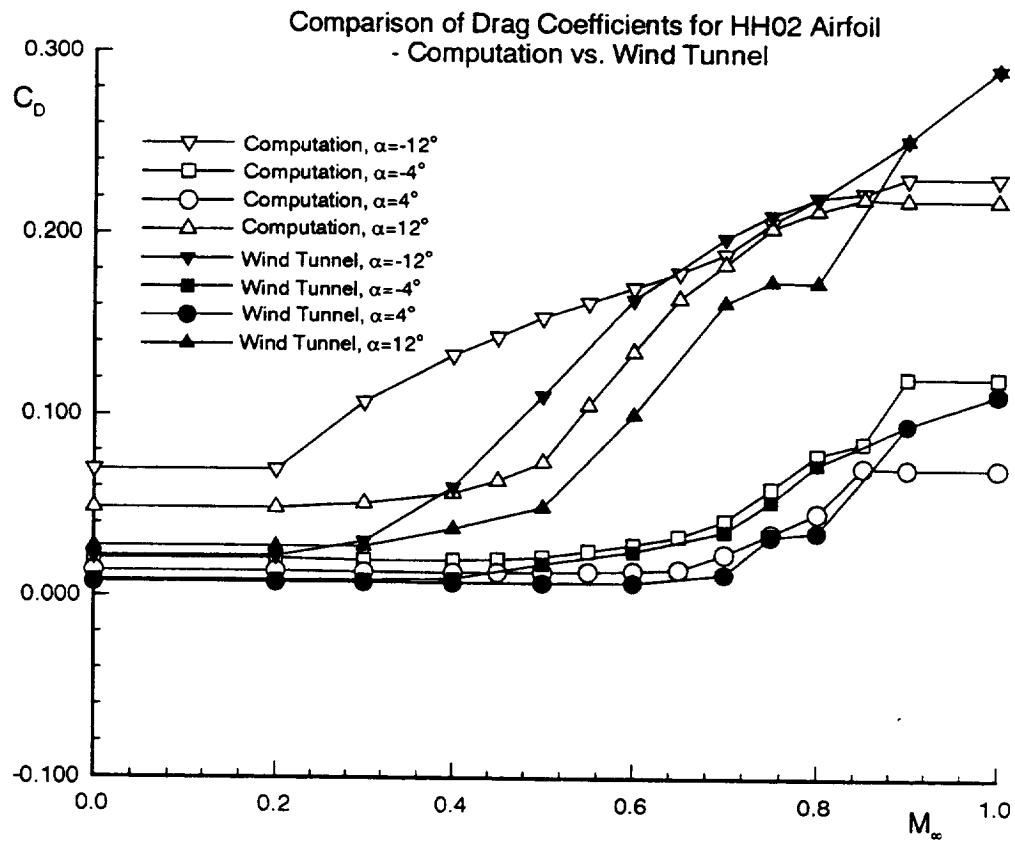
(a) $\alpha = -8^\circ, 0^\circ, 8^\circ$.

Figure 11. Comparison of drag coefficients for HH02 airfoil.



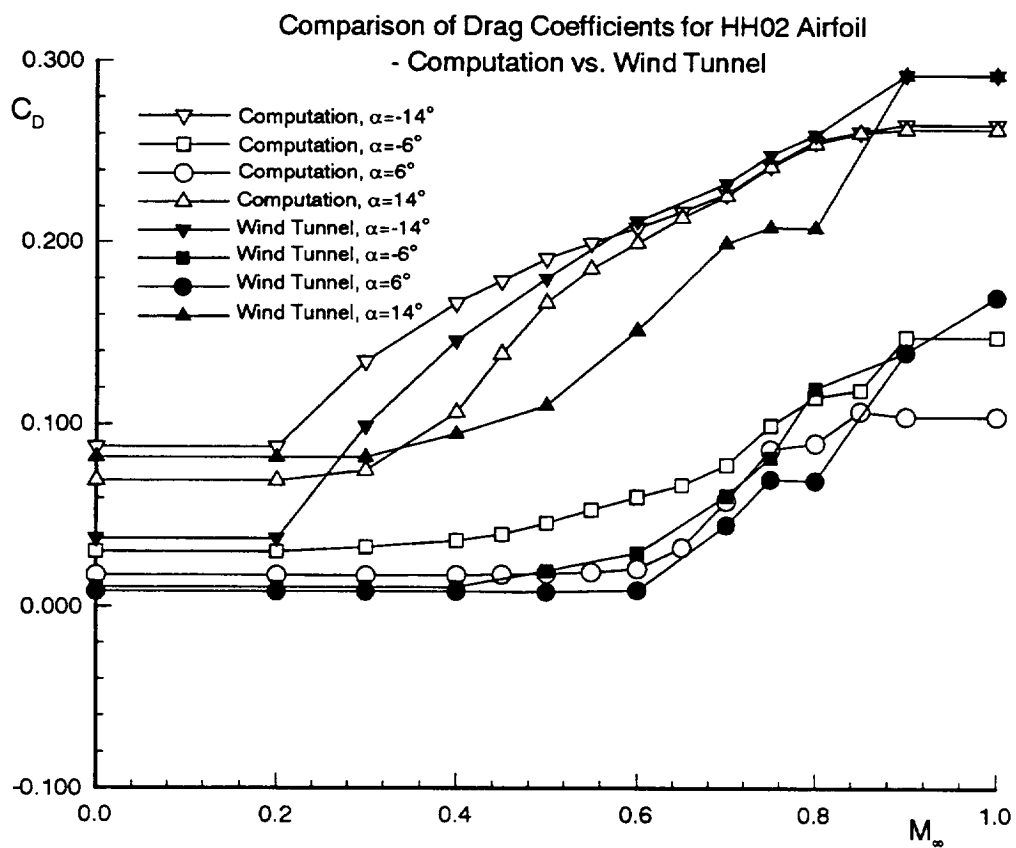
(b) $\alpha = -10^\circ, -2^\circ, 2^\circ, 10^\circ$.

(Figure 11. Continued.)



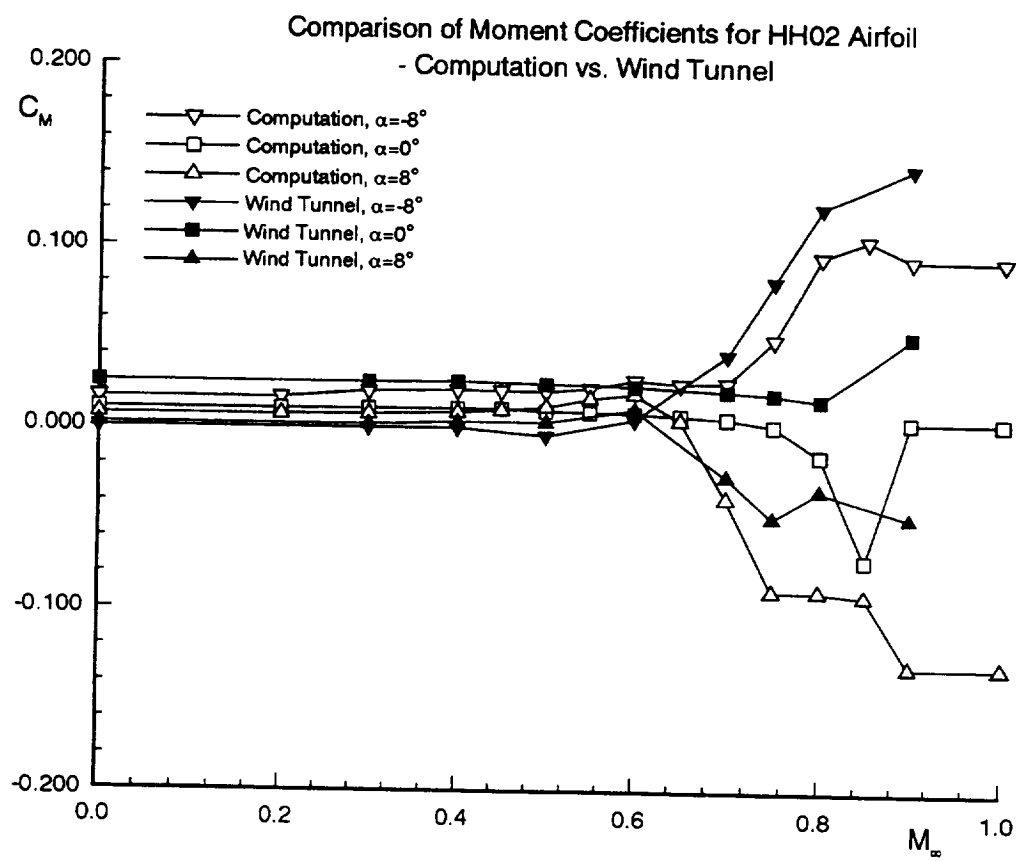
(c) $\alpha = -12^\circ, -4^\circ, 4^\circ, 12^\circ$.

(Figure 11. Continued.)



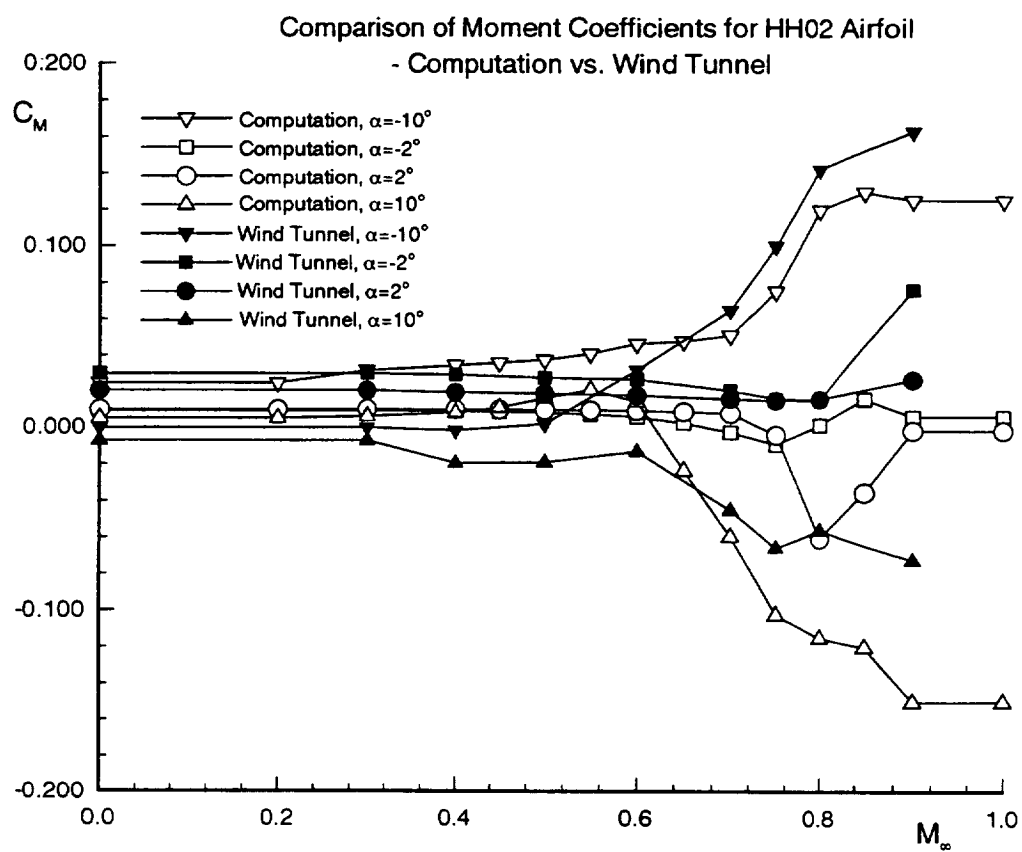
(d) $\alpha = -14^\circ, -6^\circ, 6^\circ, 14^\circ$.

(Figure 11. Continued.)



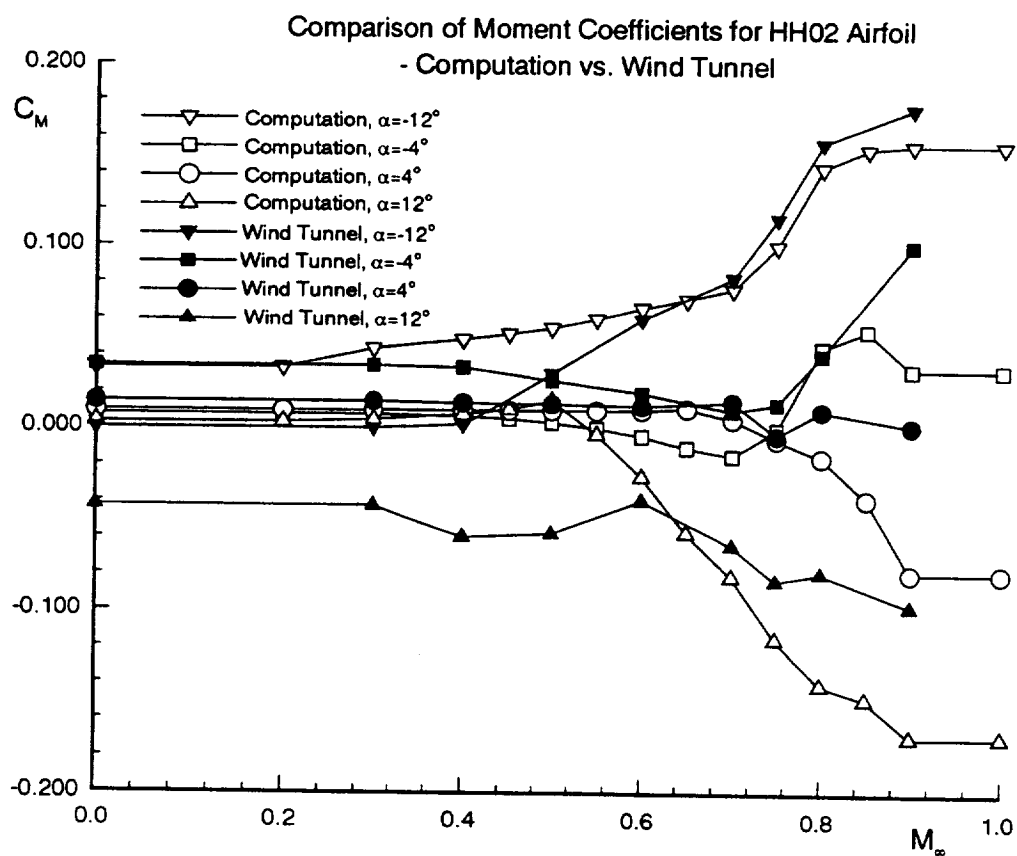
(a) $\alpha = -8^\circ, 0^\circ, 8^\circ$.

Figure 12. Comparison of moment coefficients for HH02 airfoil.



(b) $\alpha = -10^\circ, -2^\circ, 2^\circ, 10^\circ$.

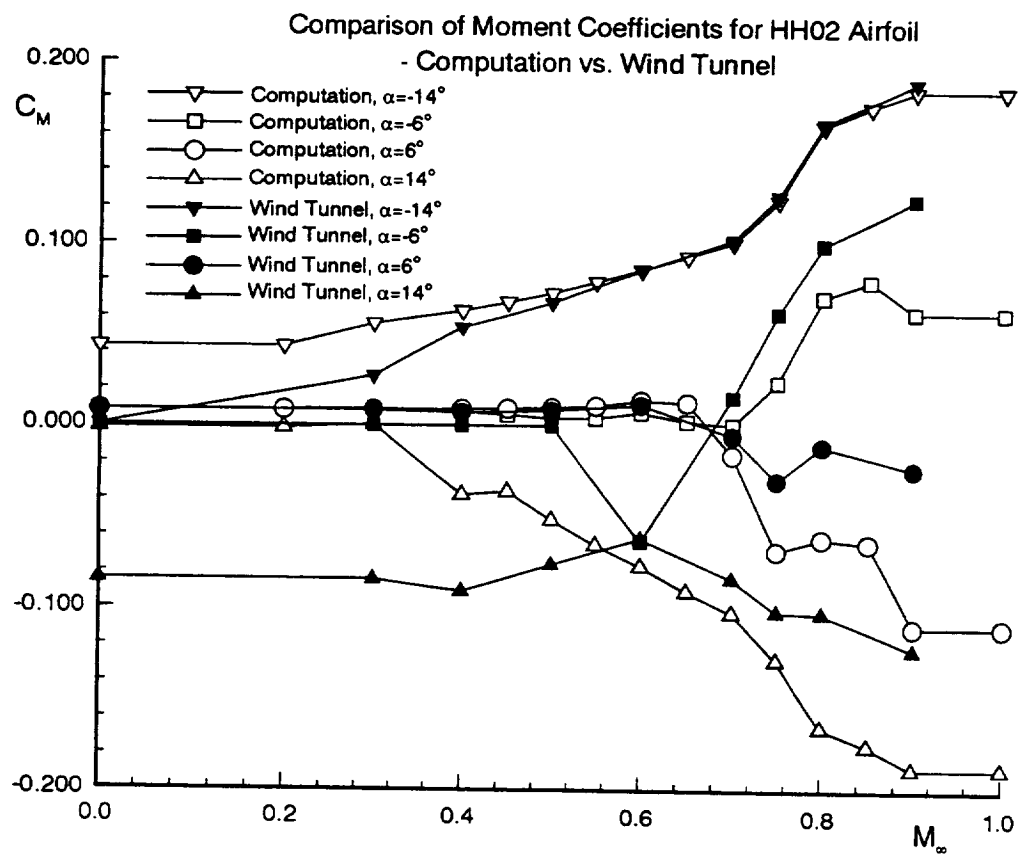
(Figure 12. Continued.)



(c) $\alpha = -12^\circ, -4^\circ, 4^\circ, 12^\circ$.

(Figure 12. Continued.)

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 07704-0188	
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13. ABSTRACT (Maximum 200 words) The report documents the study of the application of the TRAC airfoil table computational package (TRACFOIL) to the prediction of 2D airfoil force and moment data over a wide range of angle of attack and Mach number. The TRACFOIL generates the standard C-81 airfoil table for input into rotorcraft comprehensive codes such as CAM-RAD. The existing TRACFOIL computer package is successfully modified to run on Digital alpha workstations and on Cray-C90 supercomputers. A step-by-step instruction for using the package on both computer platforms is provided. Application of the newer version of TRACFOIL is made for two airfoil sections. The C-81 data obtained using the TRACFOIL method are compared with those of wind-tunnel data and results are presented.				
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(d) $\alpha = -14^\circ, -6^\circ, 6^\circ, 14^\circ$.

(Figure 12. Continued.)